Calorimeter Electronics

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sPHENIX Collaboration Meeting

11-Dec-2015

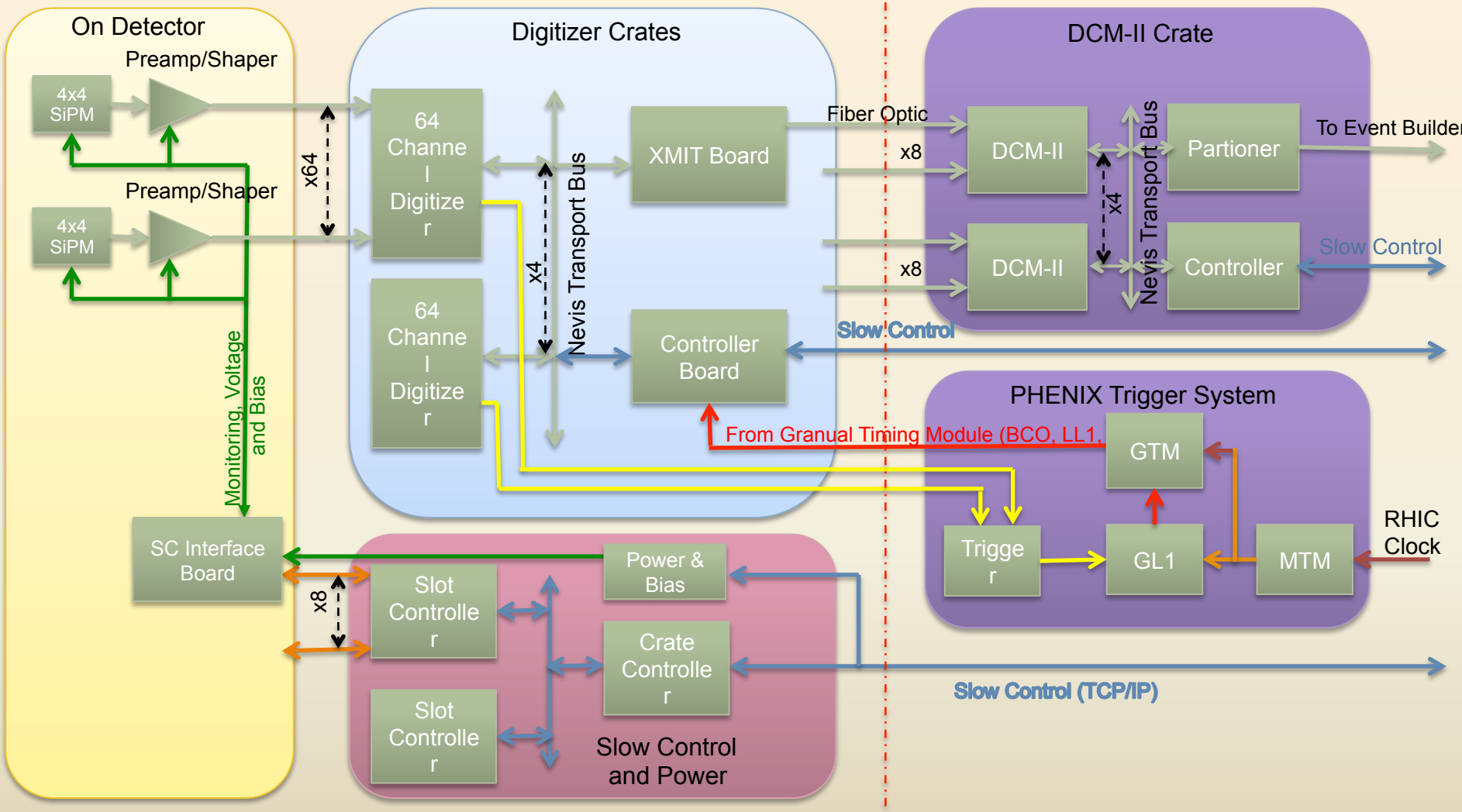
Design Drivers- I

- Compact Electronics- limited space on detector
- Common Electronics Design
  - Reduce design cost and time
  - Use off the shelf component, no custom ASICs
- Optical Sensors
  - Immune to magnetic fields
  - Compact
  - High gain
- Direct digitization of signals
  - 40 BCO latency for trigger
  - Multi-event buffering
  - Reduced demands on analog section
- Compatible with PHENIX DAQ
  - High rate: 15kHz L1 trigger rate

Design Specifications

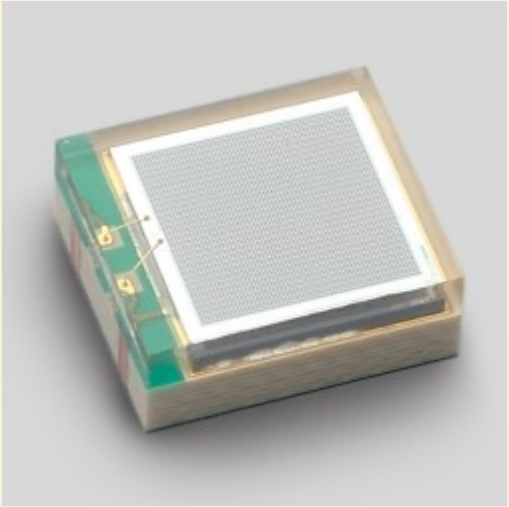
- Optical Sensors:
  - Dynamic Range: 10^4
  - Gain: 10^5
  - Photon Detection Efficiency: 25%
- Analog Front End:
  - Signal-to-Noise: 10:1
  - Peaking time: 30 nSec
  - Gain: 100 mV/pC
- Digitizer:
  - Resolution 14 bits (12 bit effective)
  - Maximum sampling frequency: 65 MHz
  - Latency (L1 Trigger): 40 Beam Crossings (BCO)
  - Multi-event buffering: 4 Events
  - L1 Trigger rate: 15 KHz

Calorimeter Electronics Overview



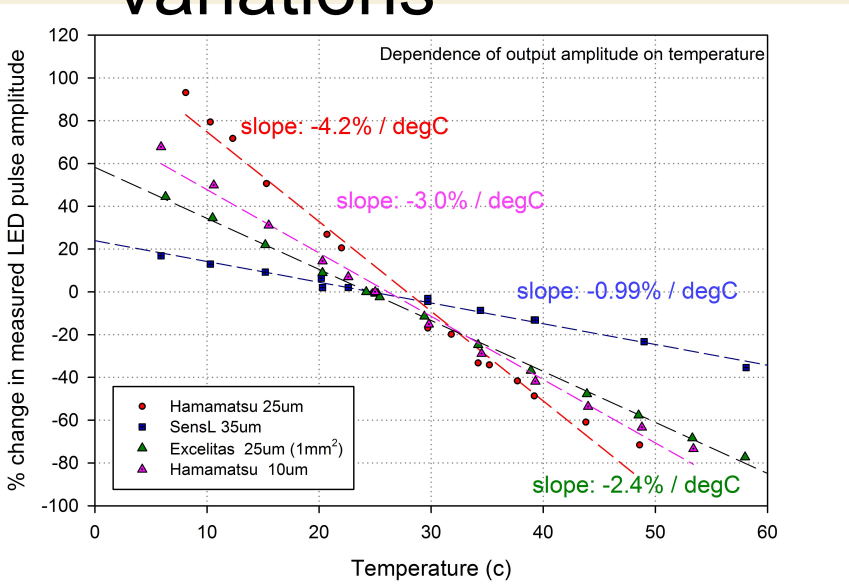
Calorimeter Electronics: Optical Sensors

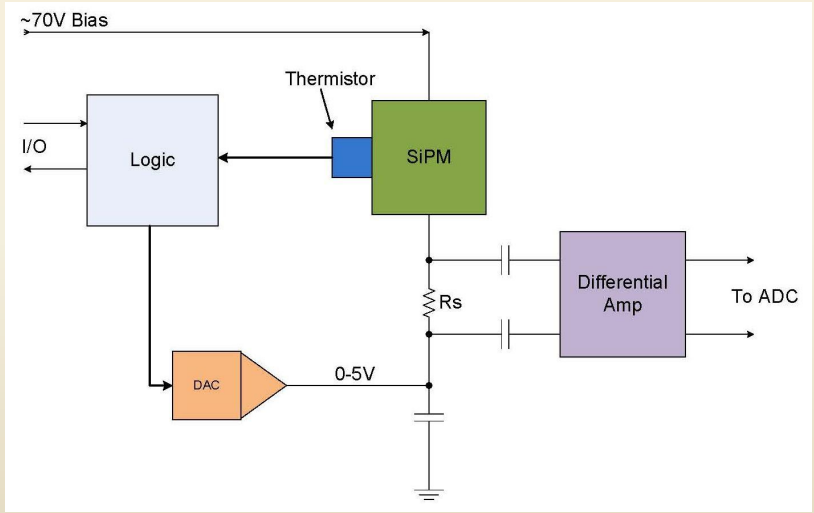
- Solid state optical sensors
  - SiPMs are the preferred sensor
  - Reference design based on Hamamatsu S12572-015P
    - 3x3 mm^2
    - 15 μm pixel size, 40K pixels
    - Gain: $2x10^5$
    - EMCal: 98304, HCal: 15360



Optical Sensors: Temperature Effects

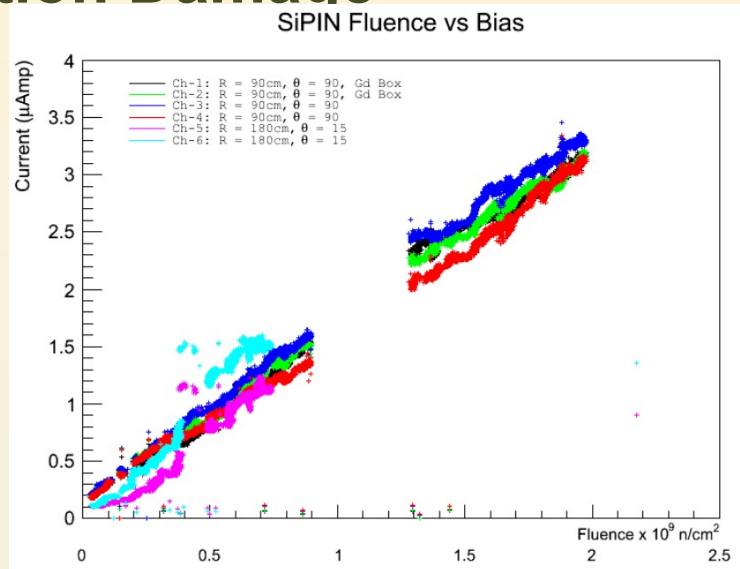
- SiPMs have strong temperature dependence : 2%-4%/^{o}C
- Local monitoring of temperature
- Feed back loop to correct for temperature variations

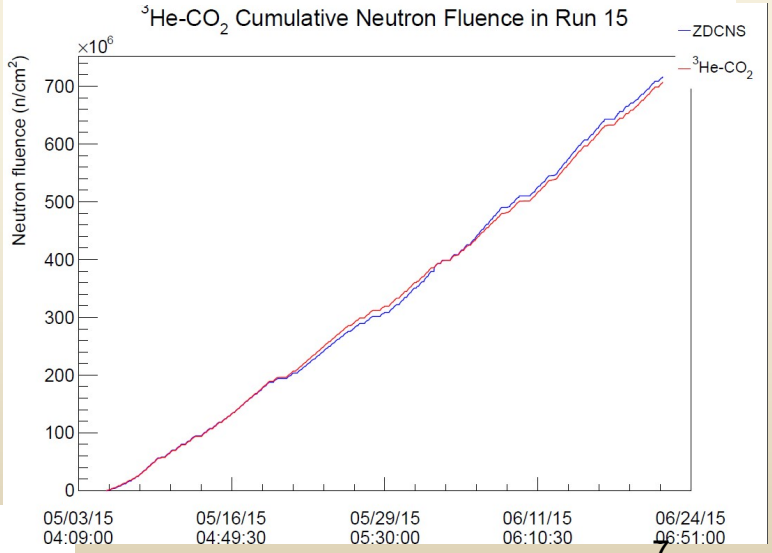




SiPM Neutron Radiation Damage

- *SiPM susceptible to damage due to neutron radiation*
- *Results in increased leakage current*
  - *Increased noise*
  - *Decrease in PDE*
  - *Increased power*
- *Studies on neutron damage in progress*

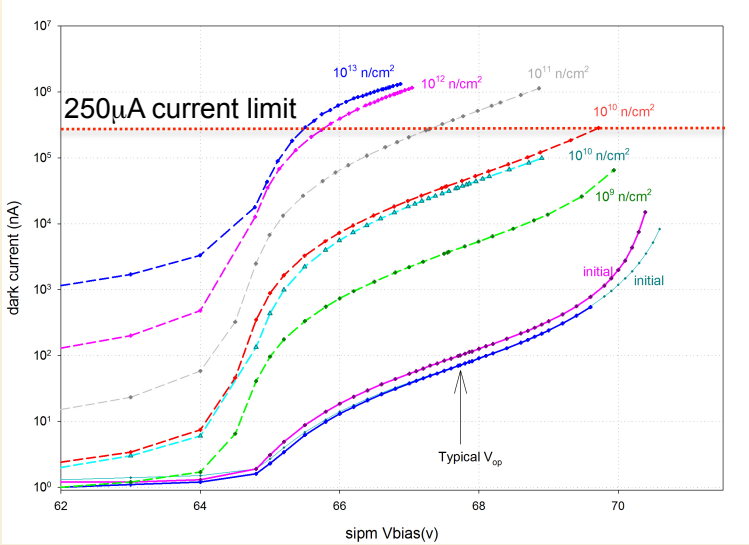


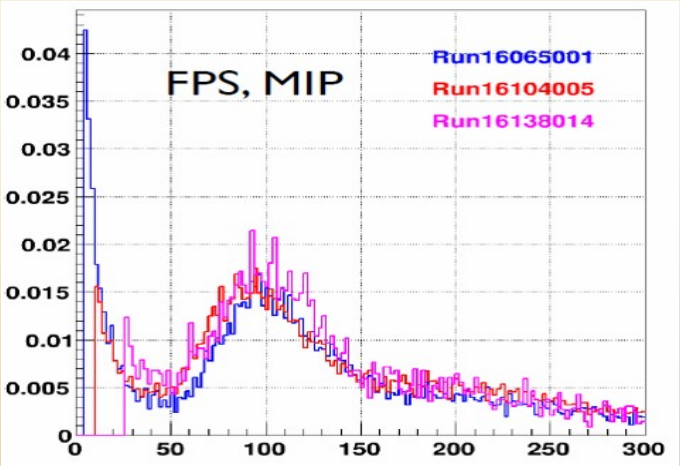


PHENIX

SiPM Radiation Studies

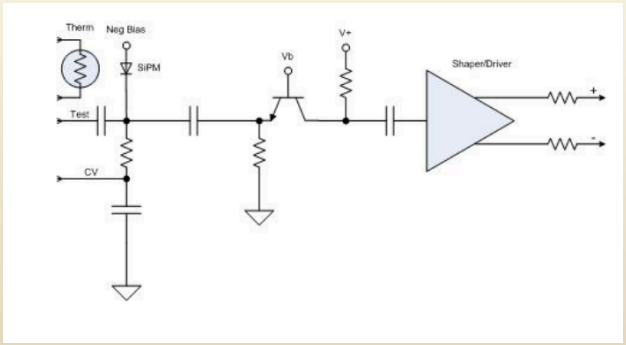
- *PHENIX IR: Run 14/15*
  - *Neutron fluxes similar to what is expected for sPHENIX 2-3 x 10^{10} n/cm^2 per Run*
  - *Measure change in leakage current*
  - *Measure gain using LEDs*
- *LANCE (Los Alamos) and LENS (Indiana University) Studies*
  - *Much higher fluences- Equivalent to multi-years of running in a few days 10^{11} – 10^{13} n/cm^2*
  - *Study device characteristics pre/post irradiation*
- *STAR is also doing studies*

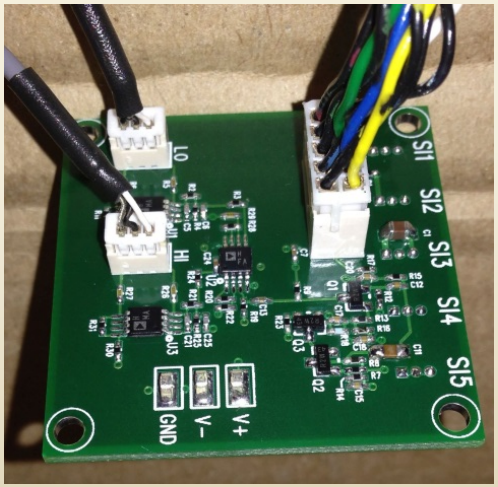




Calorimeter Electronics: Analog Electronics

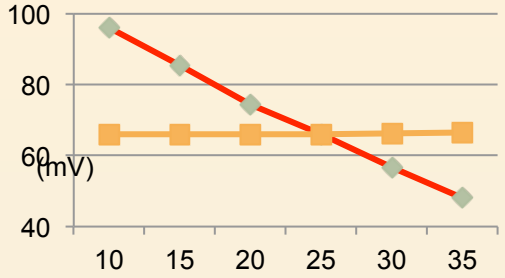
- Common front end analog electronics
  - Analog electronics located on detector.
  - Local thermistor for temperature monitoring: Trim SiPM bias +/- 2.5V
  - Charge injector signal test: Test Pulse
  - Differential multiple-feedback Shaper/Driver – 30nSec peaking time matched to a 60 MHz sampling rate.
  - S/N approximately 1 μcell (pixel)
  - Low power: P_{tot} ~ 300 mW

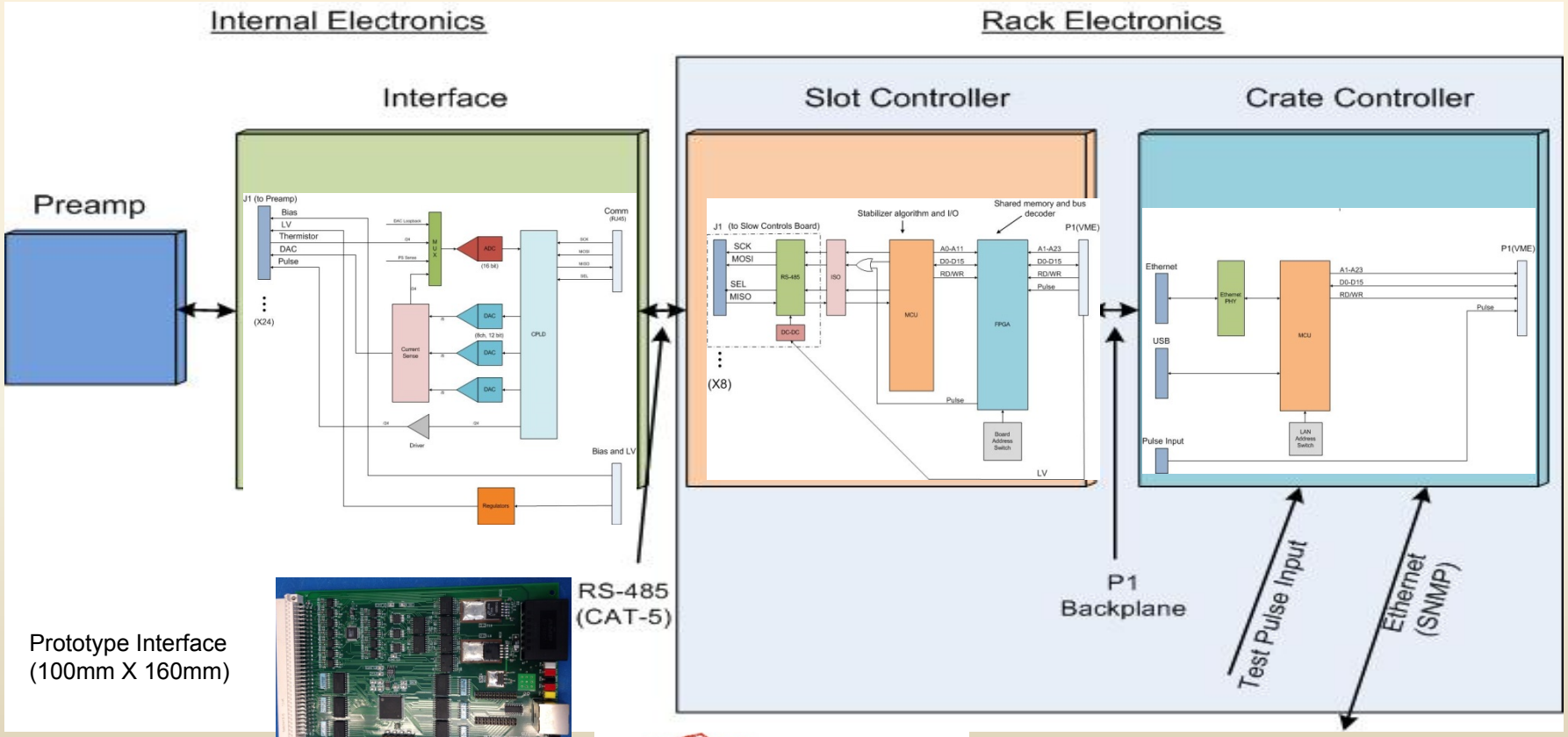




Slow Controls

- Monitor temperature and currents
- Compensate for temperature and variations in leakage current

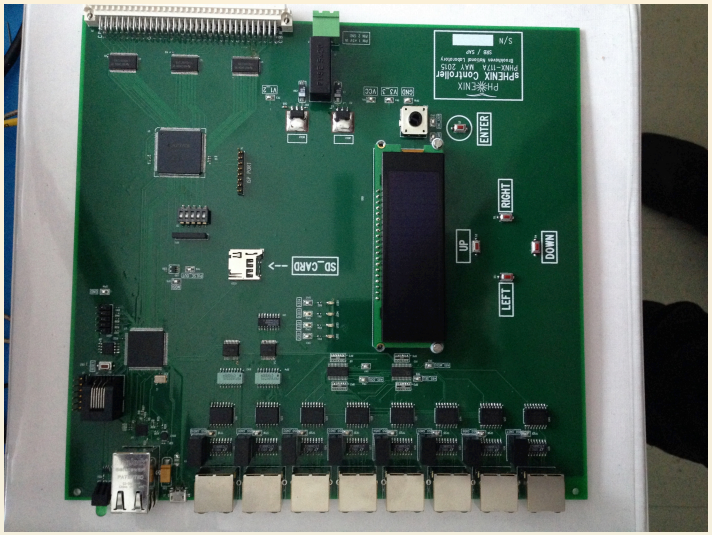




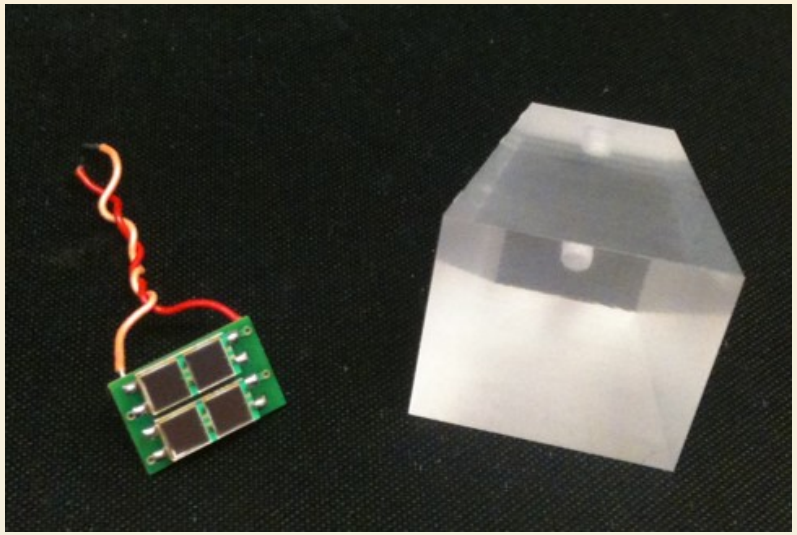
Prototype Interface
(100mm X 160mm)

Front End Prototypes

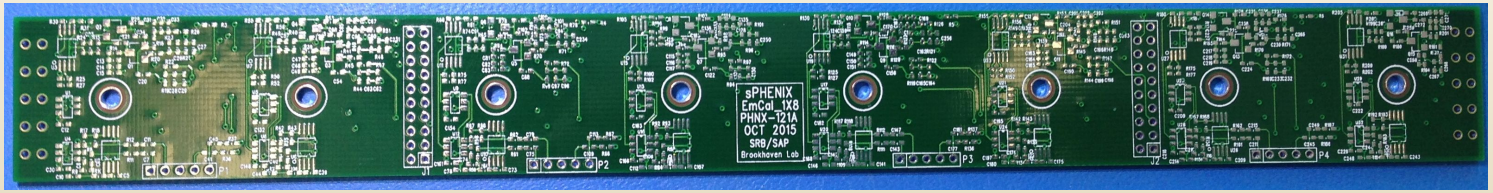
HCal Controller



EMCal SiPM Holder



EMCal 1x8 Preamplifier Board

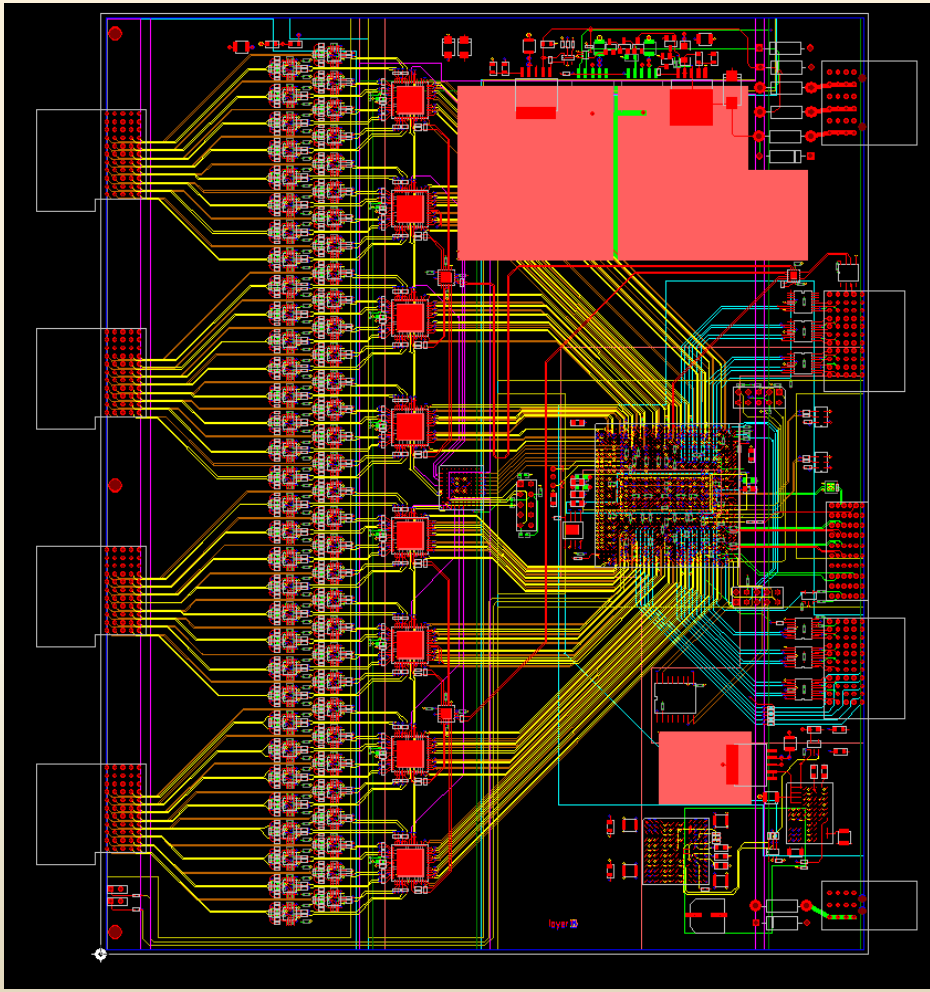


Calorimeter Electronics: Digital

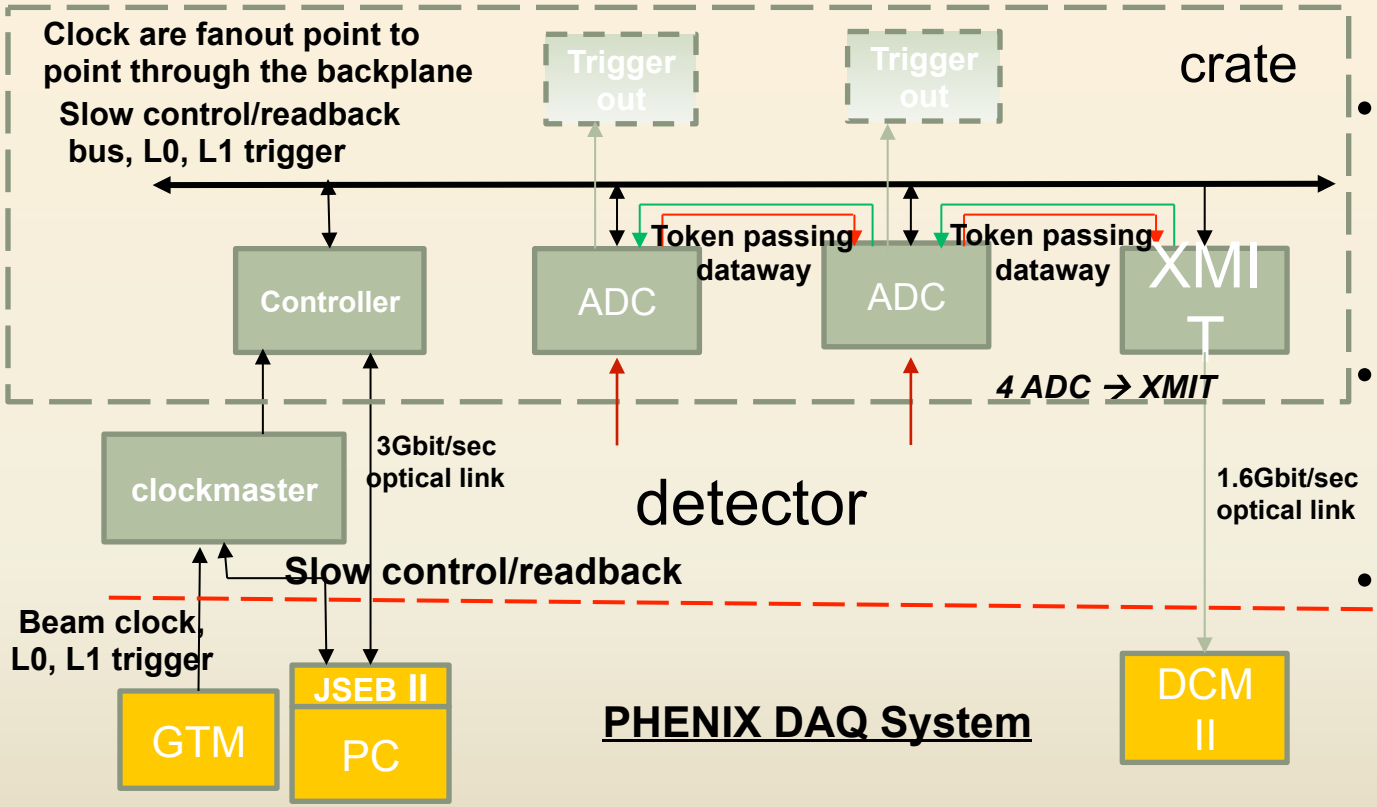
- Located off (but near) detector
  - Reduced space constraints
  - Reduced cooling complexity
  - Easier access for installation and maintenance
  - Reduced magnetic constraints: e.g. allows use of DC-DC converters, inductors.
  - Need to pay attention to noise issues
- Continuous digitization of signals
  - 6x Beam crossing (BCO) frequency
  - 14 Bit ADC
  - Digital 40 BCO latency for L1 Trigger
  - Multi-event buffering
  - Provides trigger primitives

DIgitizer System

- Based on PHENIX HBD design
- 14 Bit ADC @ ~60 MHz
- 64 channels per board
- Trigger Primitives based on 2x2 tower geometry
- First R&D prototypes are in fab with testing fall of 2015
- Should be available for 2016 beam test

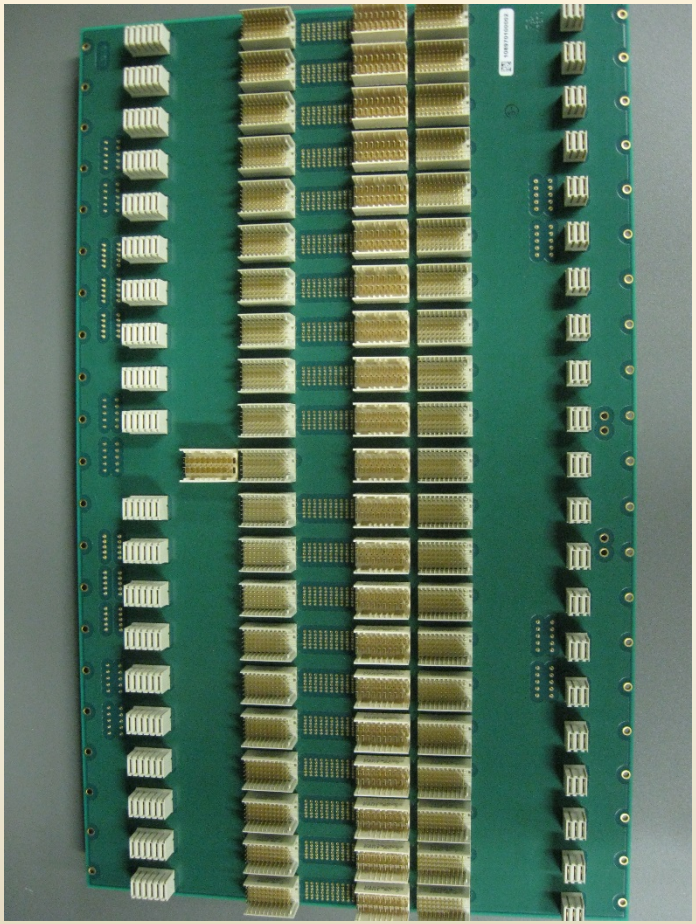


sPHENIX Digitizer System

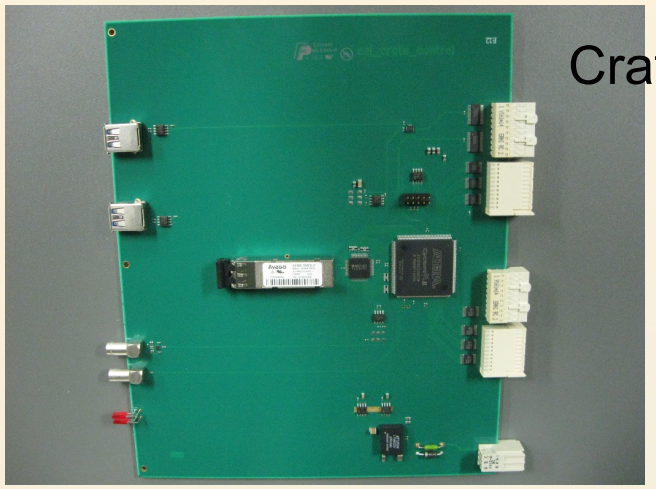


- Crate based system
- Differential signals from on detector eletronics
- Generate L1 Trigger primitives
- Send digitized data out when L1 request received

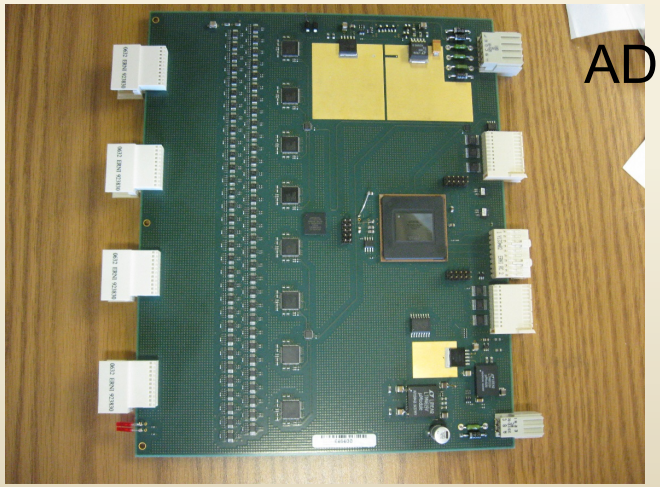
Digitzers are a Reality



Backplane



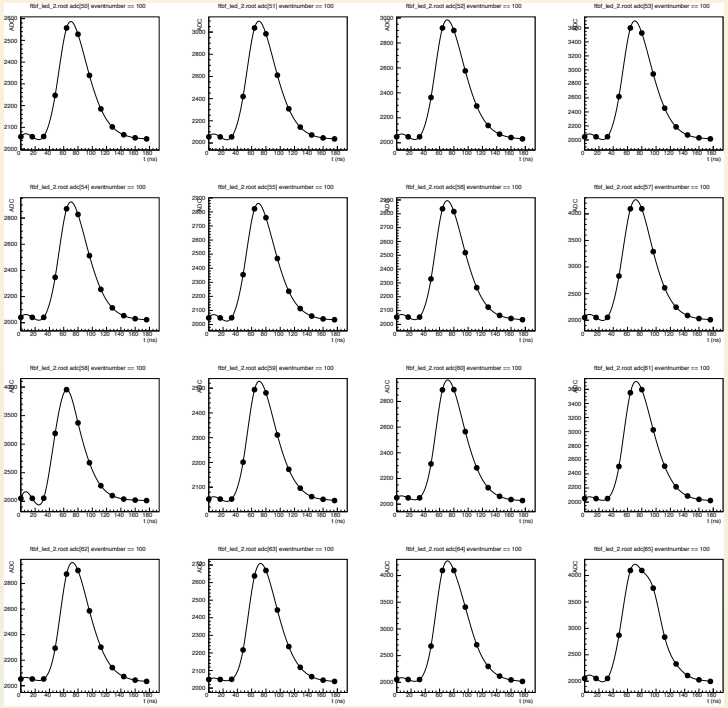
Crate Controller



ADC Board

Calibration and Monitoring

- Preamplifiers have built in charge injection.
  - System testing and monitoring
  - Electronics calibration
- LED Pulsar system system built into preamp boards
  - Pulsed through slow control system
  - Illumination of light guides
  - Experience in PHENIX: MPC, ZDC…
- Gain compensation by controlling SiPM overvoltage (Temperature stabilization circuit)
- Ultimate calibration offline using π^0 peak PHENIX EMCal



LED signal observed in
EMCal test beam prototype
Using HBD readout electronics

Opportunities for Contributions: Calorimeter Electronics

- SiPM Characterization:
  - Temperature effects
  - Radiation damage
  - Neutron fluence
- Calibration/Monitoring:
  - EMCal: LEDs + ???
  - Hcal: LEDs + Cosmics
  - Electronics: Gain, Temperature, Currents….
- Electronics prototyping:
  - Lab testing and characterization
  - Beam tests

Opportunities for Contributions: Calorimeter Electronics…

- Production Work
  - Final Design
  - Production oversight
  - Quality assurance
  - Installation and final check out
- EMCal/HCal Trigger
  - Design of trigger algorithm
  - Development and testing of Trigger components
- Cooling:
  - EMCal and HCal have similar but different constraints
  - Coupled with monitoring and gain stabilization

Summary

- We have a concept for the EMCal and HCal electronics:
  - Same optical sensor, almost the same analog front end
  - Direct digitization of SiPM signals
  - Provides trigger primitives based on tower sums
- First generation prototypes show that the concept is feasible
  - Continue studies on the SiPMs: radiation, temperature, stability
  - Still lot's of work to be done to test and characterize the prototypes
  - Test Beam on the horizon- April 2016
- There is still a lot of work to be done to prepare for CD1 & CD2/3
  - Flesh out the remaining pieces of the design
  - Work out production, Q/A and installation plans
  - Design a robust calibration and monitoring plan
- Bi-Weekly meetings, next is Wednesday Dec 16 @ 1330 EST
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